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**APPLICATION
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LETTERS PATENT**

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FOR: WHITE LIGHT EMITTING DEVICE

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WHITE LIGHT EMITTING DEVICE

The present application is based on Japanese patent application No. 2002-286089, the entire contents of which are
5 incorporated herein by reference.

Technical Field

The present invention relates to a white light emitting device having a light emitting element and phosphors to emit
10 a white light, and which is applied to, for example, an LED display, a backlight device, a signal device, an illumination type switch, a variety of sensors, a variety of indicators and the like.

15

Background Art

In general, a light emitting element used for a light emitting device includes an inorganic LED (Light Emitting Diode), an organic LED, a laser diode, an inorganic thick film electroluminescence sheet or an inorganic thin film
20 electroluminescence parts and the like. Among others, LED stands out in characteristics such as long life, space-saving, good resistance to impact shock, and further, capable of emitting a light in a narrow spectral band.

A number of luminous colors, i.e. a number of luminous
25 colors in a particularly wide spectral band cannot be realized or can be realized only in an inefficient manner by light emission inherent to an active semiconductor material in LED. Especially, such tendency is remarkable in case of white light emission.

According to the well-known technical level, a luminous color which cannot be essentially realized is attained by a wavelength conversion technique. The wavelength conversion technique is essentially based on the following principle.

5 Namely, at least one phosphor is placed on an LED, and the light emitted from the LED is absorbed by the phosphor to emit a light having a wavelength different from that of the light absorbed. In other words, a light emitted is absorbed by an LED, and then, a photoluminescence light is radiated with another luminous

10 color.

As a light emitting device emitting a light of white color based on the principle as described above, a white LED lamp wherein a light emitted from a purple LED is wavelength-converted by phosphors of respective colors of

15 red/green/blue (hereinafter referred to as "red/green/blue phosphors in case of expressing collectively) which are in practical use at present, to emit a light is well known. Respective components of the red/green/blue phosphors are as follows.

20 Red phosphor: $\text{La}_2\text{O}_2\text{S}:\text{Eu}$, Sm (YOS:Eu)

Green phosphor: $3(\text{Ba}, \text{Mg}, \text{Eu}, \text{Mn})\text{O}\cdot8\text{Al}_2\text{O}_3$ (BAM:Eu, Mn)

Blue phosphor: $(\text{Sr}, \text{Ca}, \text{Ba}, \text{Eu})_{10}(\text{PO}_4)_6\cdot\text{Cl}_2$

However, there is such a problem that color rendering properties are low in a conventional white light emitting device

25 (white LED lamp).

FIG. 1 is a spectral diagram indicating emission intensity of a conventional white LED lamp. As shown in the figure, since there is scarcely a yellow component having a wavelength of 560 to 590 nm, an average color rendering evaluation number Ra of

the white LED lamp is as low as about **50** to **60**. In a usual fluorescent lamp, an average color rendering evaluation number Ra is about **80** to **90**, and ideal is **100**.

On the other hand, in a white light emitting device wherein
5 white color is realized by a combination of a blue LED and a phosphor, an emission wavelength of the blue LED shifts to a long wavelength side with increase of temperature rise, so that there is a case where color deviation appears in the white light emitting device.

10 An object of the present invention is to provide a white light emitting device having improved color rendering properties.

Furthermore, another object of the present invention is to provide a white light emitting device in which color
15 deviation is hard to appear.

Disclosure of Invention

(A) According to the present invention, a white light emitting device comprising:

20 a light emitting element having a peak wavelength of **500** nm or less;

a first phosphor absorbing a light emitted from the light emitting element and emitting a light having a yellow wavelength different from a wavelength of the light absorbed; and

25 a second phosphor having an emission wavelength different from at least that of the first phosphor is provided.

The above-described white light emitting device may have any of the following limitations or a combination thereof.

1) The above-described emission wavelength is a peak

wavelength of **400** nm or less.

2) The above-described second phosphor includes one or more of phosphors having blue through red emission wavelengths.

3) The above-described second phosphor includes any or all **5** of phosphors emitting a blue light, a red light, and a green light, respectively.

4) The above-described first phosphor is an alkaline earth metal silicate.

5) The above-described first phosphor is an alkaline earth **10** metal silicate activated with europium.

6) The above-described first phosphor is an alkaline earth metal orthosilicate activated with divalent europium represented by a formula:

15
$$(2-x-y) \text{SrO} \cdot x (\text{Ba, Ca}) \text{O} \cdot (1-a-b-c-d) \text{SiO}_2 \cdot a \text{P}_2\text{O}_5 b \text{Al}_2\text{O}_3 c \text{B}_2\text{O}_3$$

$$d \text{GeO}_2 : y \text{Eu}^{2+}$$

wherein **0 < x < 1.6**, **0.005 < y < 0.5**, **0 < a, b, c, d < 0.5**; and/or an alkaline earth metal orthosilicate represented by a formula:

20
$$(2-x-y) \text{BaO} \cdot x (\text{Sr, Ca}) \text{O} \cdot (1-a-b-c-d) \text{SiO}_2 \cdot a \text{P}_2\text{O}_5 b \text{Al}_2\text{O}_3 c \text{B}_2\text{O}_3$$

$$d \text{GeO}_2 : y \text{Eu}^{2+}$$

wherein **0.01 < x < 1.6**, **0.005 < y < 0.5**, **0 < a, b, c, d < 0.5**; in this case, at least one of the values **a, b, c, and d** is advantageously more than **0.01**.

25 **7)** The above-described red, green, blue and/or yellow phosphor(s) is (are) mixed into a covering member covering the light emitting element.

8) The above-described red, green, blue and/or yellow phosphor(s) to be mixed into the covering member is (are) mixed into at the vicinity of the light emitting element in a high

density condition.

9) The above-described red, green, blue and/or yellow phosphor(s) is (are) further mixed also into an insulative adhesive material for fixing the light emitting element to a
5 lead frame.

(B) According to another aspect of the present invention, a white light emitting device comprising:

a light emitting element made of a GaN-based semiconductor and emitting a purple light which is disposed in a cup of a mount
10 lead; and

a sealant made of a transparent resin filled in the cup and sealing the light emitting element;

red, green, and blue phosphors absorbing a light emitted from the light emitting element and emitting red, green, and
15 blue lights of wavelengths different from that of the light absorbed, respectively, and a yellow phosphor absorbing a light emitted from the light emitting element and emitting a yellow light of a wavelength different from that of the light absorbed being mixed into the sealant is provided.

20 The above-described white light emitting device may have the following limitations.

The above-described white light emitting device comprises further a lens-shaped mold member made of a transparent resin and covering the cup filled with the sealant and a part of the
25 mount lead.

(C) According to a further aspect of the present invention, a white light emitting device, comprising:

a light emitting element made of a GaN-based semiconductor and emitting a purple light which is disposed in a cup of a mount

lead;

a sealant made of a transparent resin filled in the cup and sealing the light emitting element;

5 a lens-shaped mold member made of a transparent resin and covering the cup filled with the sealant and a part of the mount lead; and

10 a fluorescence cover fitted to the mold member and to which red, green, and blue phosphors absorbing a light emitted from the light emitting element and emitting red, green, and blue lights of wavelengths different from that of the light absorbed, respectively, are mixed into;

15 a yellow phosphor absorbing a light emitted from the light emitting element and emitting a yellow light of a wavelength different from that of the light absorbed is mixed into the fluorescence cover is provided.

(D) According to a still further aspect of the present invention, a white light emitting device comprising:

20 a light emitting element emitting a purple light; and a substantially rectangular light guidance plate guiding a light emitted from the light emitting element to outgo the light from a light-outgoing surface;

25 red, green, and blue phosphors absorbing a light emitted from the light emitting element and emitting red, green, and blue lights of wavelengths different from that of the light absorbed, respectively, and a yellow phosphor absorbing a light emitted from the light emitting element and emitting a yellow light of a wavelength different from that of the light absorbed being applied onto the light-outgoing surface of the light guidance plate is provided.

(E) According to an yet further aspect of the present invention, a white light emitting device comprising:

a light emitting element emitting a purple light;

a substantially rectangular light guidance plate guiding

5 a light emitted from the light emitting element to outgo the light from a light-outgoing surface; and

a film to which red, green, and blue phosphors absorbing a light emitted from the light emitting element and emitting red, green, and blue lights of wavelengths different from that

10 of the light absorbed, respectively, are mixed into;

a yellow phosphor absorbing a light emitted from the light emitting element and emitting a yellow light of a wavelength different from that of the light absorbed being mixed into the film is provided.

15

Brief Description of Drawings

FIG. 1 is a spectral diagram indicating emission intensity of a conventional white LED lamp.

20 **FIG. 2** is a sectional view showing a white LED lamp according to a first embodiment of the present invention.

FIG. 3 is a diagram showing a layer structure of a purple LED in a white LED lamp.

FIG. 4 is a spectral diagram indicating emission intensity of the white LED according to the first embodiment.

25 **FIG. 5** is a sectional view showing a white LED lamp according to a second embodiment of the present invention.

FIG. 6 is a sectional view showing a white LED lamp according to a third embodiment of the present invention.

FIG. 7 is a circuit diagram showing an overvoltage

protection device using a Zener diode in the white LED lamp according to the third embodiment.

FIG. 8 is a circuit diagram showing an overvoltage protection device using a capacitor in the white LED lamp according to the third embodiment.

FIG. 9 is a sectional view showing a white LED lamp according to a fourth embodiment of the present invention.

FIG. 10(a) is a plan view showing a device for a planar light source according to a fifth embodiment of the present invention, and **FIG. 10(b)** is a sectional view taken along the line A-A of **FIG. 10(a)**.

Best Mode for Carrying out the Invention

In the following, embodiments according to the present invention will be described in detail by referring to the accompanying drawings.

(First Embodiment)

FIG. 2 is a sectional view showing a white LED lamp according to a first embodiment of the present invention.

The white LED lamp **10** shown in **FIG. 2** is an SMD (Surface Mounted Device) type, and has the following structure. Electrically insulated two lead frames **14** and **15** are formed on the upper, lower and side surfaces of an insulative glass-epoxy resin substrate **12** in a gold pattern, and a frame **17** made of a plastic and having a cup **17a** is disposed on the lead frames **14** and **15**. A surface of the cup **17a** is a reflecting mirror reflecting a light emitted from a purple LED **19**. The lead frames **14** and **15** are asymmetrical to each other wherein the upper surface of the lead frame **15** is formed beyond a central portion

of the bottom of a space provided by the cup **17a** of the frame **17**, while the other lead frame **14** is formed to somewhat expose into the bottom of the space.

The purple LED **19** emits a purple light of **395 nm**, and fixed 5 to the upper surface of the lead frame **15** by a mount **21** prepared from a silver filler-containing epoxy resin paste and the like. In this case, however, the purple LED **19** may be replaced by another LED emitting any of lights in a wavelength region of **350 to 400 nm**. A p-electrode of the purple LED **19** is connected 10 to the lead frame **15** through a gold bonding wire **23**, while an n-electrode of the purple LED **19** is connected to the lead frame **14** through a gold bonding wire **24**.

The space formed in the frame **17** is filled with a sealant **26** which comes to be transparent after being cured, and the 15 purple LED **19** is secured with the sealant **26**. The sealant **26** is made of silicone resin or epoxy resin, and the sealant **26** is mixed with a yellow phosphor **31** being a characteristic element of the present invention (which will be described in detail hereinafter) in addition to a red phosphor **28**, a green 20 phosphor **29**, and a blue phosphor **30** which are explained in a conventional example.

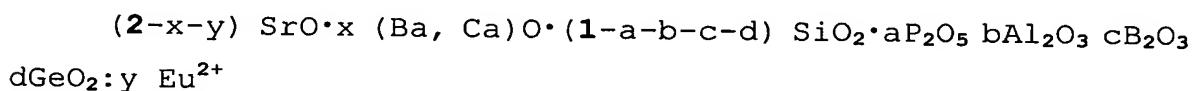
It is to be noted that either the sealant **26** into which the red, green, blue, and yellow phosphors **28** to **31** are mixed may fill up the whole space in the cup **17a** formed in the frame 25 **17**, or it may fill up a section extending from the upper edge of the frame **17** to a region positioned under the upper edge. Moreover, a diffusion material diffusing a light may be mixed into the sealant **26** admixed with the red, green, blue, and yellow phosphors **28** to **31**. In this case, a light emitted from the

purple LED **19** is reflected diffusely by the diffusion material to become a scattered light, so that the light emitted from the purple LED strikes easily on the red, green, and yellow phosphors **28** to **31**, whereby light intensity of the light
5 radiated from the red, green, blue, and yellow phosphors **28** to **31** increases. The diffusion material is not specifically limited, but well-known materials may be used.

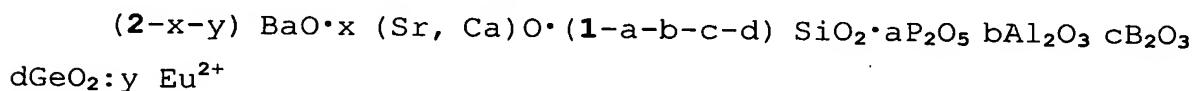
The yellow phosphor **31** is radiated as a result of subjecting **395** nm wavelength of a purple light emitted from the
10 purple LED **19** to wavelength conversion into **560** to **590** nm wavelength of a yellow light. In the sealant **26** into which the red, green, blue, and yellow phosphors **28** to **31**, inclusive, are mixed, a mixing ratio is desirable to be around **5%** in volume ratio with respect to the whole volume of the mixture including
15 the sealant **26**.

The yellow phosphor **31** is made of an alkaline earth metal orthosilicate activated with divalent europium.

Namely, the yellow phosphor **31** may be an alkaline earth metal orthosilicate activated with divalent europium
20 represented by a formula:



where **0 < x < 1.6**, **0.005 < y < 0.5**, **0 < a, b, c, d < 0.5**
and/or an alkaline earth metal orthosilicate activated
25 with divalent europium represented by a formula:



where **0.01 < x < 1.6**, **0.005 < y < 0.5**, **0 < a, b, c, d < 0.5**.

In the above case, advantageous is in that at least one of values a, b, c, and d is more than **0.01**.

More specifically, it has been found surprisingly that when a mixed form of strontium silicate or barium silicate and 5 strontium silicate orthosilicate is used in place of barium silicate, a wavelength of a light radiated becomes longer. Emission spectrum is influenced by a substitution of germanium for a silicon part, and P_2O_3 , Al_2O_3 and/or B_2O_3 existing additionally, so that the emission spectrum may be adjusted most 10 suitably in case of applying the respective components.

Advantageously, the phosphor **31** has another phosphor selected from the group of alkaline earth metal aluminates activated with divalent europium and/or manganese and/or Y (V, P, Si) $O_4:Eu$ or a further phosphor emitting a light having a 15 color near to red selected from the group of alkaline earth metal-magnesium-disilicate: Eu^{2+} , Mn^{2+} represented by the following formula:



where **0.005 < x < 0.5**, **0.005 < y < 0.5**, Me is Ba and/or 20 Sr and/or Ca.

Furthermore, it has been found that when a small amount of a monovalent ion, particularly a halide is incorporated into a phosphor lattice, it is advantageous as to degree of crystallization and emissivity. It is advantageous that a 25 spectral range is in **300 to 500 nm**. In such wavelength region, the yellow phosphor **31** is well excited.

Moreover, important steps for fabrication of the yellow phosphor **31** will be described.

For the fabrication of a silicate phosphor, stoichiometric

amounts of starting materials of alkaline earth metal carbonate, silicon dioxide, and europium oxide are intimately mixed with each other in response to a selected composition, and the mixture is converted into a desired phosphor at temperatures 5 of **1100°C** and **1400°C** under the reducing atmosphere in accordance with a solid state reaction for the fabrication of phosphor in common use. In this case, it is advantageous for crystallinity to add aluminum chloride or the other halides in a small ratio of preferably less than **0.2** mol with respect to a reaction 10 mixture. According to needs, a part of silicon may be replaced by germanium, boron, aluminum, phosphor, and a part of europium may be replaced by manganese. The operation is made by addition of corresponding amounts of compounds of the above-described elements which are thermally decomposed into oxides. In this 15 case, a range of the reaction conditions is maintained.

The resulting silicate emits a light having a wavelength of **10 nm to 600 nm**, and has a half value width of up to **110 nm**.

Luminous colors having defined color temperatures and high color reproducibility can be obtained by the use of any one of 20 phosphors from the above-described groups or phosphors obtained by combining those from the above-described groups, or alkaline earth metal aluminates activated with divalent europium and/or manganese, further additional phosphors emitting a light having a color near to red from a group of $Y (V, P, Si)O_4:Eu^{2+}$, $Y_2O_2S:Eu^{3+}$, 25 and a combination of phosphors from the groups with phosphors in common use. The fact is as shown in the following examples:

$T = 2778K$ (**464 nm** + $Sr_{1.4}Ba_{0.6}SiO_4:Eu^{2+}$) ; $x = 0.4619$, $y = 0.4247$,
 $Ra = 72$,

$T = 2950K$ (**464 nm** + $Sr_{1.4}Ba_{0.6}SiO_4:Eu^{2+}$) ; $x = 0.4380$, $y = 0.4004$,

Ra = 73,

T = 3497K (464 nm + Sr_{1.6}Ba_{0.4}SiO₄:Eu²⁺) ; x = 0.4086, y = 0.3996,

Ra = 74,

T = 4183K (464 nm + Sr_{1.9}Ba_{0.08}Ca_{0.02}SiO₄:Eu²⁺) ; x = 0.3762,

5 y = 0.3873, Ra = 75,

T = 6624K (464 nm + Sr_{1.9}Ba_{0.02}Ca_{0.08}SiO₄:Eu²⁺) ; x = 0.3101,

y = 0.3306, Ra = 76,

T = 6385K (464 nm + Sr_{1.6}Ba_{0.4}SiO₄:Eu²⁺ + Sr_{0.4}Ba_{1.6}SiO₄:Eu²⁺) ;

x = 0.3135, y = 0.3397, Ra = 82,

10 T = 4216K (464 nm + Sr_{1.9}Ba_{0.08}Ca_{0.02}SiO₄:Eu²⁺) ; x = 0.3710,

y = 0.3696, Ra = 82,

T = 3954K (464 nm + Sr_{1.6}Ba_{0.4}SiO₄:Eu²⁺ + Sr_{0.4}Ba_{1.6}SiO₄:Eu²⁺ + YVO₄:Eu³⁺) ; x = 0.3756, y = 0.3816, Ra = 84,

T = 6489K (464 nm + Sr_{1.6}Ba_{0.4}SiO₄:Eu²⁺ + Sr_{0.4}Ba_{1.6}SiO₄:Eu²⁺ + barium magnesium aluminate:Eu²⁺) ; x = 0.3115, y = 0.3390, Ra = 66,

T = 5097K (464 nm + Sr_{1.6}Ba_{0.4}(Si_{0.08}B_{0.02})O₄:Eu²⁺ + Sr_{0.6}Ba_{1.4}SiO₄:Eu²⁺) ; x = 0.3423, y = 0.3485, Ra = 82,

20 T = 5084K (464 nm + Sr_{1.6}Ba_{0.4}(Si_{0.08}B_{0.02})O₄:Eu²⁺ + Sr_{0.6}Ba_{1.4}SiO₄:Eu²⁺ + strontium magnesium aluminate:Eu²⁺) ; x = 0.3430, y = 0.3531, Ra = 83,

T = 3369K (464 nm + Sr_{1.4}Ba_{0.6}Si_{0.95}Ge_{0.05}O₄:Eu²⁺) ; x = 0.4134, y = 0.3959, Ra = 74,

25 T = 2787K (466 nm + Sr_{1.4}Ba_{0.6}Si_{0.98}P_{0.02}O₄:Eu²⁺) ; x = 0.4630, y = 0.4280, Ra = 72,

T = 2913K (464 nm + Sr_{1.4}Ba_{0.6}Si_{0.98}Al_{0.02}O₄:Eu²⁺) ; x = 0.4425, y = 0.4050, Ra = 73.

Next, the mount 21 for the white LED lamp 10 will be described.

For the mount **21** (binding material), a variety of resins such as epoxy resin may be used in view of easiness in handling. A resin used for the mount **21** has adhesiveness, besides the resin preferably is electrically insulative in such that even when 5 the mount **21** rises along sides of the purple LED **19** having a very small shape, the respective layers do not short-circuit between them.

The mount **21** permits the light emitted isotropically from the purple LED **19** to be pervious, and to reflect the light by 10 a reflecting mirror on a surface of the cup **17a**, then the light reflected is emitted upwards the white LED lamp **10**. For this reason, a transparent resin is used for the mount. In this case, since the white LED lamp **10** is a white light source, the mount **21** may have white color which does not interfere with a white 15 light.

Furthermore, the red/green/blue/yellow phosphors **28** to **31** may be contained in the mount **21**. Since the purple LED **19** emits a light isotropically, and the light is reflected also by a surface of the cup **17a**, these lights transmit through the mount 20 **21**, so that optical density is extremely high in the mount **21**. In this respect, when the red/green/blue/yellow phosphors **28** to **31** are contained in the mount **21**, the light emitted from the purple LED **19** is reflected by the red/green/blue/yellow phosphors **28** to **31** in the mount **21**, and on one hand, a light 25 is newly emitted isotropically as that excited by the red/green/blue/yellow phosphors **28** to **31** in the mount **21**. As described above, when the red/green/blue/yellow phosphors **28** to **31** are also contained in the mount **21**, the white LED lamp **10** becomes further high luminous.

Moreover, a resin containing an inorganic material such as Ag may be used for the mount **21**. When the high luminous white LED lamp **10** is used for a long period of time, the mount **21** or the sealant **26** made of a synthetic resin disposed at the very 5 vicinity of the purple LED **19** is colored in brown or black, resulting in deterioration, whereby its luminous efficiency decreases. This is because a resin such as silicone resin, and epoxy resin is used for the mount **21** and the sealant **26**. In this respect, particularly coloring of the mount **21** at the 10 vicinity of the purple LED **19** reduces remarkably its luminous efficiency. The mount **21** is required to have not only weatherability against deterioration of the resin due to a light from the purple LED **19**, but also adhesiveness, adhesion and the like. Such deterioration of resin due to a light may be solved 15 by employing a resin containing an inorganic material such as Ag in the mount **21**. Such mount **21** can be easily formed by admixing an Ag paste and the red/green/blue/yellow phosphors **28** to **31** with a mounting paste, applying the resulting admixture on the lead frame **15** by mounting equipment, and the purple LED 20 **19** is bonded thereto.

Furthermore, silicone resin containing an inorganic material may be used as an organic resin for the mount **21** other than the epoxy resin containing Ag. As an inorganic material used in the mount **21**, it is required to have good adhesion with 25 respect to a resin, and no deterioration by the light from the purple LED **19**. Thus, at least one inorganic material selected from silver, gold, aluminum, copper, alumina, silica, titanium oxide, boron nitride, tin oxide, zinc oxide, and ITO is contained in a resin. Particularly, silver, gold, aluminum,

copper and the like make heat dissipation properties better, besides exhibit electroconductivity, so that they are applicable for semiconductor device which expects electroconductivity. Moreover, alumina, silica, titanium 5 oxide and the like exhibit high weatherability, so that high reflection coefficient can be maintained by them. Inorganic materials may have a variety of forms such as spherical, needle-, flake-formed and the like forms with taking dispersion properties, electroconductivity and the like into 10 consideration. A content of an inorganic material in a resin of the mount **21** may be adjusted variously in accordance with heat dissipating properties, electroconductivity and the like desired. However, when a content of an inorganic material increases in a resin, adhesive properties decrease. Thus, it 15 is arranged in such that the content ranges from 5% by weight or more to 80% by weight or less. In this respect, however, when the content is to be from 60% by weight or more to 80% by weight or more, deterioration of a resin can be more suitably prevented.

20 In addition, when the red/green/blue/yellow phosphors **28** to **31** are also contained in the mount **21**, luminance of the white LED lamp **10** can be more elevated.

As a result, such white LED lamp **10** which is extremely slight decrease in luminous efficiency even in an application 25 under a high luminous condition and for a long period of time, and capable of emitting a high luminous light can be provided. Besides, when a material having good thermal conductivity is used, characteristic properties of the purple LED **19** can be stabilized, and it results in reduction of irregular colors.

In the following, a layer structure of the purple LED 19 will be described.

FIG. 3 shows a layer structure of the purple LED 19 wherein the purple LED 19 has, for example, a sapphire substrate 41 as 5 a transparent substrate. On the sapphire substrate 41, nitride semiconductor layers, for example, a buffer layer 42, an n-type contact layer 43, an n-type cladding layer 44, an MQW (multi-quantum well) active layer 45, a p-type cladding layer 46, and a p-type contact layer 47 are sequentially formed in 10 accordance with MOCVD method or the like. Furthermore, a transmittive electrode 50 is formed on the whole surface of the p-type contact layer 47, a p-electrode 48 is formed on a part of the transmittive electrode 50, and an n-electrode 49 is formed on a part of the n-type contact layer 43 in accordance 15 with sputtering method, vacuum evaporation technique or the like.

The buffer layer 42 is made of, for example, AlN, and the n-type contact layer is made of, for example, GaN. The n-type cladding layer 44 is made of, for example, $\text{Al}_y\text{Ga}_{1-y}\text{N}$ ($0 \leq y < 1$), the p-type cladding layer is made of, for example, $\text{Al}_x\text{Ga}_{1-x}\text{N}$ ($0 < x < 1$), and the p-type contact layer 47 is made of, for example, GaN. Moreover, a bandgap of the p-type cladding layer 46 is made larger than that of the n-type cladding layer 44. The n-type cladding layer 44 and the p-type cladding layer 46 may 20 be in a structure of a single composition, respectively, and the structure may be in such that the above-described nitride semiconductor films which have different compositions from one another and a film thickness of 100 angstrom or less are laminated so as to form a superstructure. When a film thickness 25

is **100** angstrom or less, generation of cracks and crystal defects in a film can be prevented.

The MQW active layer **45** is composed of a plurality of well layers made of InGaN and a plurality of barrier layers made of **5** AlGaN. Furthermore, each thickness of the well layers and the barrier layers is **100** angstrom or less, and preferably **60** to **70** angstrom so as to constitute a superstructure layer. Since **10** nature of crystal in InGaN is flexible as compared with that of another nitride semiconductor containing Al such as AlGaN, when InGaN is used for a layer constituting the active layer **45**, it becomes difficult to appear cracks over the whole **15** respective nitride semiconductor layers laminated. Moreover, the MQW active layer **45** may be composed of a plurality of well layers made of InGaN and a plurality of barrier layers made of **20** GaN. Furthermore, the MQW active layer **45** may be composed of a plurality of well layers made of AlInGaN and a plurality of barrier layers made of AlInGaN. In this case, however, bandgap **25** energy in the barrier layers is made larger than that of the well layers.

20 A reflection layer may be formed on sides extending from the MQW active layer **45** to the sapphire substrate **41**, for example, on a side of the buffer layer **42** of the n-type contact layer **43**. Moreover, a reflection layer may be formed on a surface opposed to the surface of the sapphire substrate **41** onto which **25** the MQW active layer **45** has been laminated. The reflection layer is preferred to have the maximum reflection coefficient with respect to the light emitted from the active layer **45**, for example, the reflection layer may be prepared from Al or a multiple layer film of a GaN-based thin film. Due to provision

of a reflection layer, the light emitted from the active layer 45 can be reflected by the reflection layer, internal absorption of the light emitted from the active layer 45 can be reduced, an output light directing upwards can be increased, and 5 light-injection to the mount 21 can be decreased to prevent optical deterioration.

In the white LED lamp 10 constructed as described above, a voltage is applied across the lead frames 14 and 15, the purple LED 19 emits a purple light having 395 nm wavelength.

10 **FIG. 4** is a spectral diagram indicating emission intensity of the white LED according to the first embodiment wherein the purple light excites the respective red/green/blue/yellow phosphors 28 to 31 in the sealant 26, and the respective red/green/blue/yellow phosphors 28 to 31 excited emit the light 15 having the respective blue/green/yellow/red colors as shown in the spectral diagram of emission intensity of **FIG. 4**. In this case, the yellow phosphor 31 is excited with a purple light to emit a yellow light having 560 to 590 nm.

Although such light obtained by mixing a purple light with 20 lights having the respective colors of blue/green/yellow/red in the sealant 26 leaks out, the resulting mixed light is recognized by human eyes to be white, and as a result, it seems that the white LED lamp 60 emits a white light.

As described above, according to the white LED lamp 10 of 25 the first embodiment, emission intensity of the respective blue/green/yellow/red colors can be totally elevated as is understood from a comparison of **FIG. 4** with **FIG. 1** cited in a conventional example. Accordingly, color components of the respective blue/green/yellow/red colors wavelength-converted

by the respective red/green/blue/yellow phosphors **28** to **31** become sufficient, so that color rendering properties can be elevated. Furthermore, a conventional average color rendering evaluation number of about **50** to **60** can be improved to about **5** **80** to **90**, and in addition, a conventional luminous intensity of about **160** mcd can be elevated to **250** mcd.

Besides, when the red/green/blue/yellow phosphors **28** to **31** are mixed into the sealant **26**, a vicinity of the purple LED **19** may be kept at a high density. In this case, since a lot **10** of lights are wavelength-converted at the vicinity of the purple LED **19**, it becomes possible to observe as if a light source is smaller, when the white LED lamp **10** is observed from the outside.

(Second Embodiment)

FIG. 5 is a sectional view showing a white LED lamp **15** according to the second embodiment of the present invention wherein parts in the second embodiment shown in **FIG. 5** corresponding to those of **FIG. 2** are designated by the same reference characters as those of **FIG. 2**, respectively.

A white LED lamp **60** shown in **FIG. 5** is that of a lens type **20** wherein a purple LED **19** is attached to a metal stem **62** through a mount **21**, the metal stem **62** in a form of a cup **17a** functioning as a reflecting mirror so as to reflect a light emitted from the purple LED **19** towards the direction over the white LED lamp **60**. The metal stem **62** is monolithically formed with one **64** of **25** lead frames, one of electrodes of the purple LED **19** on the metal stem **62** is connected with the lead frame **64** through a gold bonding wire **23**, and the other electrode is connected with a lead frame **65** through a gold bonding wire **24**.

Furthermore, the inside of the cup **17a** is covered with a

sealant **26** being a coating material for the sake of fixing the purple LED **19**. Moreover, the lead frame **65** and the lead frame **64** formed together with the metal stem **62** are sealed with an external resin **69** being a molding material. Accordingly, the **5** purple LED **19** is doubly sealed with the sealant **26** and the external resin **69**. It is to be noted that the metal stem **62** and the lead frame **64** are also called by the name of a mount lead.

The interior of the cup **17a** is filled with the sealant **26** **10** so as to be held in a lower level than the horizontal surface of the upper edge of the cup **17a**. As a result, when a plurality of LEDs is disposed in a close relation, no mixed color appears among the LEDs, so that a flat panel display is realized by LEDs, whereby a picture image having good resolving power can be **15** obtained.

Red/green/blue/yellow phosphors **28** to **31** are mixed into the sealant **26**. The red/green/blue/yellow phosphors **28** to **31** have photoluminescence effects as described in the above first embodiment, so that the light emitted from the purple LED **19** **20** is absorbed to emit a light having a different wavelength from that of the light absorbed.

Low-melting glass may be used in place of silicone resin or epoxy resin used as the sealant **26**. Low-melting glass is excellent in resistance to humidity, besides it can prevent **25** invasion of ion harmful to the purple LED **19**. Moreover, since low-melting glass can transmit the light emitted from the purple LED **19** without absorbing it, no need of extra light emission with taking an amount of such absorption into consideration.

On one hand, a scattering material may be further mixed

into the sealant **26** prepared by mixing the red/green/blue/yellow phosphors **28** to **31** into silicone resin, epoxy resin, or low-melting glass. The light emitted from the purple LED **19** is reflected diffusely by such scattering material
5 to be a scattered light, so that the light emitted from the purple LED **19** comes easily into conflict with the red/green/blue/yellow phosphors **28** to **31**, whereby an amount of a light which is derived from color development of the red/green/blue/yellow phosphors **28** to **31** can be increased.
10 Such scattering material is not specifically limited, but well-known materials may be used. For the external resin **69**, epoxy resin which becomes transparent after being cured may be employed.

In the white LED lamp **60** constructed as described, when
15 a voltage is applied across the lead frames **64** and **65**, the purple LED **19** emits a light having **395** nm wavelength. This purple light excites the respective red/green/blue/yellow phosphors **28** to **31** in the sealant **26**, and the phosphors **28** to **31** excited emit lights having the respective colors of blue/green/yellow/red
20 as indicated in the spectral diagram of emission intensity of
FIG. 4. In this case, the yellow phosphor **31** is excited with a purple light to emit a yellow light having **560** to **590** nm wavelength.

Although such light obtained by mixing a purple light with
25 lights having the respective colors of blue/green/yellow/red in the sealant **26** leaks out through the external resin **69**, the resulting mixed light is recognized by human eyes to be white, and as a result, it seems that the white LED lamp **60** emits a white light.

As described above, according to the white LED lamp **60** of the second embodiment, emission intensity of the respective blue/green/yellow/red colors can be totally elevated as is understood from a comparison of **FIG. 4** with **FIG. 1** cited in a conventional example. Accordingly, color components of the respective blue/green/yellow/red colors wavelength-converted by the respective phosphors **28** to **31** become sufficient, so that color rendering properties can be elevated. On the other hand, when the red/green/blue/yellow phosphors **28** to **31** are mixed into the external resin **69**, the same effects can be obtained.

(Third Embodiment)

FIG. 6 is a sectional view showing a white LED lamp according to the third embodiment of the present invention wherein parts in the third embodiment shown in **FIG. 6** corresponding to those of **FIG. 5** are designated by the same reference characters as those of **FIG. 5**, respectively.

A white LED lamp **70** shown in **FIG. 6** is the one wherein a purple LED **19** can be protected from an overvoltage of static electricity and the like, and the structure thereof is that in which an overvoltage protection device **72** is added to the light source in the white LED lamp **60** shown in **FIG. 5**.

The overvoltage protection device **72** is in a chipped form having the same size as that of the purple LED **19**, and it is disposed in between the purple LED **19** and the mount **21**. In the present embodiment, the purple LED **19** is flip chip-mounted different from the case of **FIG. 5** due to the reason mentioned later. The overvoltage protection device **72** is provided with electrodes **74** and **75** for connecting with the purple LED **19** and a lead frame **64**. The electrode **74** is situated at a position

opposed to a p-electrode **48** as shown in **FIG. 3**. Further, the electrode **75** is situated at a position opposed to an n-electrode **49**, and it is connected electrically with a lead frame **65** through a bonding wire **24**.

5 The electrodes **74** and **75** on the overvoltage protection device **72** are connected to the p-electrode **48** and the n-electrode **49** of the purple LED **19** through gold bumps **74** and **75**, respectively.

10 For the overvoltage protection device **72**, a Zener diode which becomes an energization state, when a voltage higher than a previously arranged voltage is applied, a capacitor which absorbs a pulse voltage or the like may be used.

15 **FIG. 7** is a circuit diagram showing the overvoltage protection device **72** wherein a Zener diode is used. The Zener diode **100** as the overvoltage protection device **72** is electrically connected in parallel to the purple LED **19** in which an anode of the purple LED **19** is connected with a cathode of the Zener diode **100**, and a cathode of the purple LED **19** is connected with an anode of the Zener diode **100**. In the case **20** when an excessive voltage is applied across the lead frame **64** and the lead frame **65**, and when the voltage exceeds a Zener voltage of the Zener diode **100**, a voltage across terminals of the purple LED **19** is held in the Zener voltage, so that it does not exceed the Zener voltage. Accordingly, it is possible to **25** prevent application of an excessive voltage to the purple LED **19**, whereby the purple LED **19** can be protected from an overvoltage, so that destruction of device or appearance of performance degradation can be prevented.

FIG. 8 is a circuit diagram showing the overvoltage

protection device 72 wherein a capacitor is used. For a capacitor 102 as the overvoltage protection device 72, a chip part for surface-mount may be used. The capacitor 102 having such construction as described above is provided with

5 strip-shaped electrodes on the opposite sides thereof, and these electrodes are connected with an anode and a cathode of the purple LED 19 in parallel. When an excessive voltage is applied across the lead frame 64 and the lead frame 65, a charging current flows through the capacitor 102, and it drops

10 instantly a voltage across terminals of the capacitor 102, whereby it is adjusted so as not to increase an applied voltage to the purple LED 19, so that the purple LED 19 can be protected from overvoltage. Furthermore, in also the case when a noise containing a high-frequency component is applied, the capacitor

15 102 functions as a bypass capacitor, so that such extraneous noise can be excluded.

As described above, the purple LED 19 in the white lamp 70 shown in FIG. 6 is flip chip-mounted which is inverted upside-down with respect to the white LED lamp 60 shown in FIG.

20 5. The reason of which is in that since the overvoltage protection device 72 is provided, electrical connections come to be required for both the overvoltage protection device 72 and the purple LED 19. If the purple LED 19 and the overvoltage protection device 72 are connected through bonding wires,

25 respectively, the number of bonding operations increases, so that its productivity decreases. Besides, since touch and disconnection of bonding wires themselves increase, so that there is a fear of decreasing reliability. Thus, the purple LED 19 is flip chip-mounted. Namely, the under surface of the

sapphire substrate **41** shown in **FIG. 3** is turned to the uppermost surface, the p-electrode **48** is connected to the electrode **74** of the overvoltage protection device **72** through the gold bump **77**, and the n-electrode is connected to the electrode **75** of the **5** overvoltage protection device **72** through the gold bump **78**, whereby it is arranged in such that no connection of the bonding wires **23** and **7** to the purple LED **19** is required. It is to be noted that when the purple LED **19** is in a flip chip-mounted, the transmittive electrode **50** shown in **FIG. 3** may be replaced **10** by a non-transmittive electrode. Moreover, it may be also arranged in such that the n-electrode **49** is thickened so as to have the same height as the surface of the p-electrode **48**, or a conductor is newly connected to the n-electrode **42** and the resulting conductor is utilized as an electrode.

15 In the white LED lamp **70** of the third embodiment constructed as described above, when a voltage is applied across the lead frames **64** and **65**, lights having respective blue/green/yellow/red colors are emitted as in the case of the white LED lamp **60** shown in **FIG. 5**, so that color rendering **20** properties can be elevated as in the case of the white LED lamp **60**.

Furthermore, in the white LED lamp **70**, since the **25** overvoltage protection device **72** is provided, even when an overvoltage due to static electricity and the like is applied, there is not a case where the purple LED **19** is damaged, or a case performance deterioration arises in the purple LED **19**. Besides, since the overvoltage protection device **72** functions as a sub-mount, even if the purple LED **19** is flip chip-mounted, a height of bonding positions of the bonding wires **23** and **24**

on a chip side does not come down, and as a result, bonding can be made at a position being substantially the same height as that of the case in the white LED lamp **60** shown in **FIG. 5**.

In the case where a semiconductor device is used for the **5** overvoltage protection device **72**, a usual silicon diode may also be used in place of the Zener diode **100**. In this case, a plurality of silicon diodes is connected in series with the same polarities wherein the number of the silicon diodes to be used is determined in such that a value of total forward voltage drop **10** (about **0.7 V x number**) corresponds to an operative voltage with respect to overvoltage. In addition, a variable resistor device may also be used for the overvoltage protection device **72**. Variable resistor device has such a characteristic that a resistance value decreases with increase of an applied voltage, **15** so that it can suppress overvoltage as in the case of the Zener diode **100**.

(Fourth Embodiment)

FIG. 9 is a sectional view showing a white LED lamp according to the fourth embodiment of the present invention **20** wherein parts in the fourth embodiment shown in **FIG. 9** corresponding to those of **FIG. 5** are designated by the same reference characters as those of **FIG. 5**, respectively.

A white LED lamp **110** shown in **FIG. 9** is the one wherein the light emitted from a light emitting element is **25** wavelength-converted to radiate the resulting light outside a resin sealed body of a lens type, and which comprises a structure including lead frames **64** and **65**, a metal stem **62**, a purple LED **19**, a mount **21**, bonding wires **23** and **24**, a sealant **26** containing no red/green/blue/yellow phosphors **28** to **31**, an external resin

69, and a cup 17a, and a further structure including a transmittive fluorescence cover 112 containing the red/green/blue/yellow phosphors 28 to 31 and which adheres to the outer surface of the external resin 69 to envelops the same.

5 A resin base material of the fluorescence cover 112 is, for example, transmittive polyester resin, acrylic resin, urethane, nylon, silicone resin, vinyl chloride, polystyrol, Bakelite, CR39 (acryl-glycol-carbonate resin) and the like, and urethane, nylon, and silicone resin are easily put on the 10 external resin 69, because these resins can give elasticity of a certain degree upon the fluorescence cover 112.

Furthermore, the fluorescence cover 112 has a contour which adheres intimately to the outer surface of the external resin 69, in other words, a shape wherein a hemisphere-shaped 15 cover is formed on the upper part of a cylinder-shaped cover in accordance with one-piece molding, and the resulting fluorescence cover 112 is detachably to the external resin 69. Moreover, it is preferred that the fluorescence cover 112 is to be in a thin film-form to reduce light scattering due to the 20 red/green/blue/yellow phosphors 28 to 31. Besides, the fluorescence cover 112 is formed into a predetermined shape by injection molding of a resin containing the red/green/blue/yellow phosphors 28 to 31, and then, the resulting fluorescence cover is allowed to adhere intimately 25 to the external resin 69, whereby the operation therefor can be comparatively simply completed. In this respect, however, the fluorescence cover 112 may be formed in such that a resin raw material containing the red/green/blue/yellow phosphors 28 to 31 is directly sprayed on the external 69 to cure the resin

raw material for the sake of forming no air layer between the external resin **69** and the fluorescence cover **112**.

In the white LED lamp **110** constructed as described above, the outgoing light from the purple LED **19** is injected to the **5** fluorescence cover **112** through the sealant **26** and the external resin **69**. A part of the injected light is absorbed by the red/green/blue/yellow phosphors **28** to **31**, and wavelength-converted at the same time to be outgoing to the outside. As a result, a luminous color observed from the outer **10** surface of the fluorescence cover **112** becomes a color obtained by synthesizing these lights, for example, it is white color based on the above-mentioned principle.

As described above, according to the white LED lamp **110** of the fourth embodiment, although the sealant **26** being a resin **15** sealant body for the purple LED **19** and the external resin **69** do not contain the red/green/blue/yellow phosphors **28** to **31**, since the fluorescence cover **112** for covering the outer surface of the external resin **69** contains the red/green/blue/yellow phosphors **28** to **31**, lights having respective colors of **20** blue/green/yellow/red can be emitted as in the case of the white LED lamp **60** shown in **FIG. 5**, so that color rendering properties can be similarly elevated.

Furthermore, since the sealant **26** and the external resin **69** do not contain the red/green/blue/yellow phosphors **28** to **31**, **25** light scattering due to the red/green/blue/yellow phosphors **28** to **31** does not arise. On one hand, since the fluorescence cover **12** is formed into a thin film form, light scattering due to the red/green/blue/yellow phosphors **28** to **31** is comparatively small. Accordingly, when a shape of a lens section of the external resin

69 is formed into an arbitrary shape (a hemisphere-shape in case of the embodiment described above), a desired optical directivity is obtained, whereby deterioration in luminance accompanied with wavelength conversion can be suppressed at the 5 minimum.

In addition to such a manner that the red/green/blue/yellow phosphors 28 to 31 are contained in the fluorescence cover 112, a manner wherein the red/green/blue/yellow phosphors 28 to 31 are applied on the 10 surface of the fluorescence cover 112 can attain the same effects as that of the former manner of containment of the red/green/blue/yellow phosphors 28 to 31. Besides, the fluorescence cover 112 can put on a commercially available semiconductor light emitting element, so that a white LED lamp 15 can be manufactured inexpensively.

(Fifth Embodiment)

FIGS. 10(a) and (b) are views each showing a device for a planar light source according to the fifth embodiment of the present invention wherein **FIG. 10(a)** is a plan view, and **FIG. 20 10(b)** is a sectional view taken along the line A-A of **FIG. 10(a)**. It is to be noted that parts in the fifth embodiment shown in **FIGS. 10(a) and (b)** corresponding to those of **FIG. 2** are designated by the same reference characters as those of **FIG. 2**, respectively.

25 A device 120 for a planar light source shown in **FIG. 10** is applied as, for example, a backlight device for a liquid crystal panel. The device for a planar light source irradiates a light to a liquid crystal panel from the back side thereof to give brightness or contrast with respect to characters and

picture images on the liquid crystal panel being nonluminous, whereby its visual recognition is elevated, and the device for a planar light source comprises the following components.

More specifically, the device **120** for a planar light source
5 is composed of a transparent, substantially rectangular light guidance plate **122**, a plurality of purple LEDs **19** which are disposed on a side of the light guidance plate **122** in an array-form to be buried therein, whereby they are optically connected with the light guidance plate **122**, a light reflection
10 casing **124** for reflecting a light and attached to the light guidance plate **122** so as to surround surfaces except for a light-outgoing surface **122a** of the light guidance plate **122**, a light scattering pattern **128** obtained by forming a fine and steady concavo-convex pattern on a light reflection surface **126**
15 opposed to the light-outgoing surface **122a** of the light guidance plate **122**, and a transparent film **130** attached to the light guidance plate **122** so as to cover the light-outgoing surface **122a** and containing the red/green/blue/yellow phosphors **28** to **31** inside thereof.

20 Furthermore, the respective purple LEDs **19** are attached to the light reflection casing **124** in such that a driving voltage having a predetermined voltage is supplied from a power source through a means for supplying power source such as bonding wires, and lead frames. The light scattering pattern **128** functions
25 to scatter the lights emitted from the purple LEDs **19** inside the light guidance plate **22**.

In the device **120** for a planar light source constructed as described above, when a driving voltage is applied to the respective purple LEDs **19**, lights are outgone from the

respective purple LEDs **19** driven. The outgoing-lights proceed in the light guidance plate **122** in given directions, they collide against the light scattering pattern **128** formed on the light reflection surface **126** to be outgone from the
5 light-outgoing surface **122a** while being reflected and scattering, and they pass through the film **130** as a planar outgoing-light. The outgoing-lights of the purple LEDs **19** are partly absorbed by the red/green/blue/yellow phosphors **28** to **31** in the case when they pass through the film **130**, and they
10 are wavelength-converted at the same time to be outgone. As a result, a luminous color observed from the front of the film **130** is a color obtained by synthesizing these lights, for example, it becomes white in accordance with the above-mentioned principle.

15 As described above, according to the device **120** for a planar light source of the fifth embodiment, since it is constructed in such that the outgoing lights from the purple LEDs **19** are injected to the light guidance plate **122**, the lights injected are reflected by the light scattering pattern **128**
20 formed on the light reflection surface **126** of the light guidance plate **122** to outgo the lights from the light-outgoing surface **122a** to the film **130** while scattering them, a part of the lights is absorbed by the red/green/blue/yellow phosphors **28** to **31** in the film **130**, and at the same time, they are
25 wavelength-converted to be outgone, color rendering properties thereof can be elevated as in the case of the white LED lamp **10** shown in **FIG. 2**.

Furthermore, since a structure is the one wherein the red/green/blue/yellow phosphors **28** to **31** are not in directly

contact with the purple LEDs **19**, deterioration of the red/green/blue/yellow phosphors **28** to **31** can be suppressed for a long period of time, so that a predetermined color tone of such planar light source can be maintained for a long period

5 of time.

It is to be noted that in addition to containing the red/green/blue/yellow phosphors **28** to **31** in the film **130**, the application of the red/green/blue/yellow phosphors **28** to **31** to a surface of the film **130** results in the same advantageous

10 effects as that of the containment of the phosphors.

On one hand, although the purple LEDs **19** are optically connected to the light guidance plate **122** by burying the purple LEDs **19** in the light guidance plate **122**, the other optical connections such as adhesion bonding of the purple LEDs **19** to end surfaces of the light guidance plate **122**, and guidance of a light emitted from the purple LEDs **19** to the end surfaces of the light guidance plate **122** by means of optical conduction means such as optical fiber are also applicable. In this case, a single purple LED **19** may also be applied.

20 In the first to the fifth embodiments described above, an LED having a peak wavelength of **400 nm** or less is used, so that its emission wavelength exhibits purple color of a low degree of recognition even if it is in visible light ray or ultraviolet ray. On the other hand, a color which is sensed by human eyes
25 is a color mixture of lights emitted from LED and phosphor. For this reason, even if an emission wavelength of an LED deviates somewhat towards a long wavelength side, color deviation is hard to appear, because a degree of recognition is low with respect to the light emitted from the LED.

Furthermore, in the first to the fifth embodiments, although white color is realized by the use of phosphors of red/green/blue/yellow colors, such white color may be realized by substituting two types of an alkaline earth metal 5 orthosilicate activated with divalent europium (yellow phosphor) and a blue phosphor for these phosphors. In this case, luminance of a white light emitting device becomes high.

Industrial Applicability

10 As described above, according to the present invention, since a light of purple color emitted from a light emitting element is wavelength-converted by phosphors of respective red/green/blue/yellow colors, a light of yellow component which can be scarcely obtained by such phosphors of respective 15 red/green/blue/yellow colors can be obtained, so that color rendering properties can be elevated.

Moreover, a light emitting element having a peak wavelength of **400 nm** or less is used, so that its emission wavelength exhibits a purple color of a low degree of 20 recognition even if it is in visible light ray or ultraviolet ray. On the other hand, a color which is sensed by human eyes is a color mixture of lights emitted from LED and phosphor. For this reason, even if an emission wavelength of the LED deviates somewhat towards a long wavelength side, color deviation is hard 25 to appear, because a degree of recognition is low with respect to the light emitted from the LED.